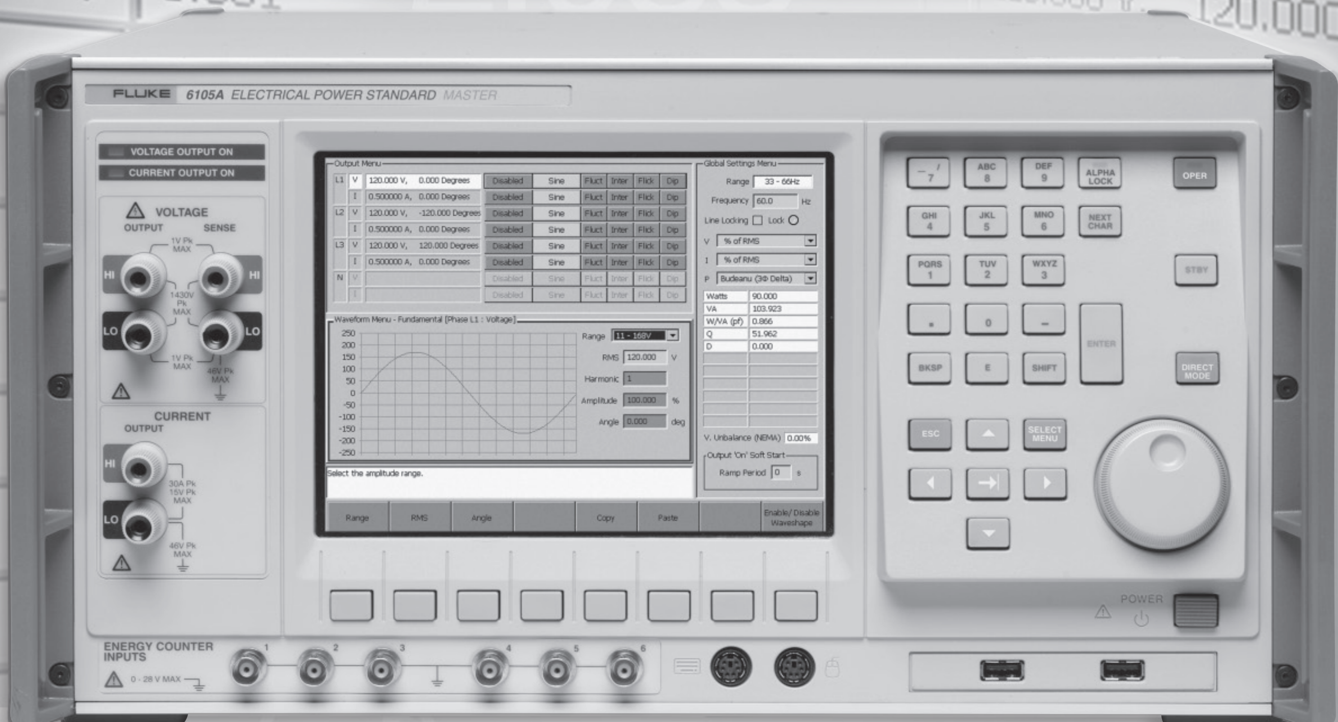
FLUKE®

Calibration

6100B/6105A Electrical Power Standards

Extended Specifications



The most accurate solutions: 6100B and 6105A

In 2002, Fluke Calibration launched the 6100A and 6101A Electrical Power Standards. The 6100A/6101A combined source stability with reference accuracy in a single product.

The 6100A and 6101A have now been replaced by the 6100B and 6101B. These newer models have the same power quality and functionality as their predecessors, to comfortably meet the accuracy requirements for power quality testing standards. In addition, they feature improved accuracy to match that of the best measurement devices for sinusoidal waveforms.

Few systems can match the 0.007 % (66 ppm) one year energy accuracy provided by the 6105A for sinusoidal waveforms. Waveforms with high harmonic distortion are delivered with similar accuracy traceable to national and international standards.

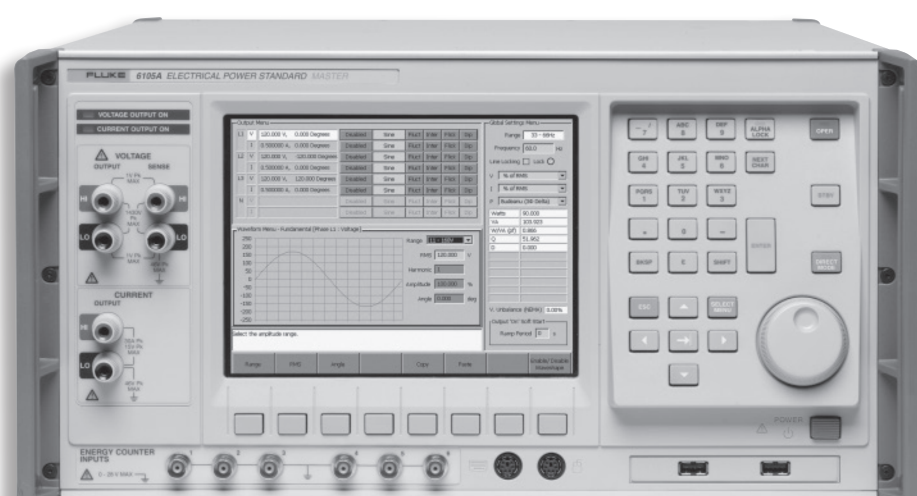
Choosing between a 6100B or 6105A depends on your accuracy requirements. Both models meet all accuracy requirements of power quality testing to the IEC 61000-4 series of standards. The 6100B can also be used to type test 0.1 % to 2 % energy meters.

Choose the 6105A when you need the highest accuracy available for calibrating secondary standard meters, energy revenue meters and type test applications.

The 6100A and 6101A also include increased voltage channel current drive, for calibrating energy meters which take power from their voltage input.

6101B

6106A



The 6105A provides the accuracy required to verify the performance of secondary standards such as those produced by Radian Research, Zera, and MTE.

6105A

FLUKE ®
Calibration

General Specifications

Input Power

Voltage	100 V – 240 V with up to ±10 % fluctuations
Transient overvoltages	Impulse withstand (overvoltage) category II of IEC 60364-4-443
Frequency	47 Hz – 63 Hz
Max. Consumption	1000 VA max from 100 – 130 V, 1250 VA max from 130 V – 260 V

Dimensions

	6100B, 6101B, 6105A, and 6106A	With 50 A or 80 A Options
Height	233 mm (9.17 inches)	324 mm (12.8 inches)
Height (without feet)	219 mm (8.6 inches)	310 mm (12.2 inches)
Width	432 mm (17 inches)	432 mm (17 inches)
Depth	630 mm (24.8 inches)	630 mm (24.8 inches)
Weight	23 kg (51 lb)	30 kg (66 lb)

Environment

Operating temperature	5 °C – 35 °C
Calibration temperature (tcal) range	16 °C – 30 °C
Storage temperature	0 °C – 50 °C
Transit temperature	-20 °C – 60 °C <100 hours
Warm up time	1 hour
Safe operating max. relative humidity (non-condensing)	<80 % 5 °C – 31 °C ramping linearly down to 50 % at 35 °C
Storage max. relative humidity (non-condensing)	<95 % 0 °C – 50 °C
Operating altitude	0 m – 2,000 m
Non-operating altitude	0 m – 12,000 m
Shock	MIL-PRF-28800F class 3
Vibration	MIL-PRF-28800F class 3
Enclosure	MIL-PRF-28800F class 3

Safety

- Meets CAN/CSA-C22.2 No 61010.1-04, UL Std. No. 61010-1 (2nd Edition), ISA-82.02.01
  Reference Standard: IEC 61010-1:2001
- Indoor use only, pollution degree 2; installation category II
- CE marked and CSA listed

EMC

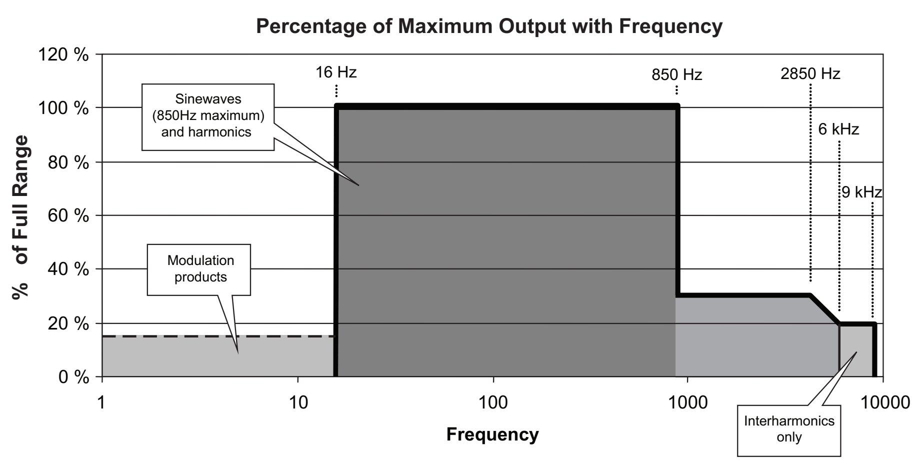
EN61326-1:2006, CISPR II Class A, FCC rules part 15, sub-part B, class A (Class A equipment is suitable for use in establishments other than domestic, and those directly connected to a low voltage power supply network which supplies buildings used for domestic purposes).

General Electrical Specifications

Voltage/Current amplitude setting resolution	6 digits
Range of fundamental frequencies	16 Hz - 850 Hz
Line frequency locking	45 Hz - 65.9 Hz at user's discretion
Frequency accuracy	±50 ppm
Frequency setting resolution	0.1 Hz
Warm up time to full accuracy	1 hour or twice the time since last warmed up
Settling time following change to the output	0 to 10 seconds
Nominal angle between voltage phases	120 °
Nominal angle between voltage and current of a phase	0 °
Phase angle setting	±180 °, ± π radians [1]
Phase angle setting resolution	0.001 °, 0.00001 radians [1]
Maximum number of voltage harmonics	100 including the 1st (fundamental frequency)
Maximum number of current harmonics	100 including the 1st (fundamental frequency)

[1] Switching between phase set in degrees, phase set in radians and back may not be consistent because of calculation rounding errors.

Amplitude/Frequency Limits



- If the 50 A or 80 A option is fitted, the range minimum settable fundamental frequency is 40 Hz and the maximum harmonic frequency is 3 kHz.
- Although the minimum settable fundamental frequency is 16 Hz, modulated waveforms may generate frequency components below that, including DC.
- A DC component of up to 50 % of range may be added to all voltage and current ranges except 50 A and 80 A.
- If the bandwidth limit is enabled, maximum frequency is 1.5 kHz.

Open and Closed Loop Operation

Full accuracy for pure sine or sine plus harmonics is achieved by using analog and digital feedback systems (closed loop). When any of: Flicker, Fluctuating harmonics, Dip/Swell or Interharmonics are applied, the digital system is automatically uncoupled (open loop). Initial performance is as described in the 1-year accuracy column but performance degrades with time as described by the stability column. Full accuracy can be restored by momentarily disabling whichever of Flicker, Fluctuating harmonics, Dip/Swell or Interharmonics are enabled, or by changing the value of the sine wave or any harmonic for that channel.

Electrical Specifications

The accuracies stated include the calibration uncertainty provided by Fluke Service Centers. In the following specifications, uncertainty is stated at coverage factor k = 2, equivalent to 96 % confidence level, in accordance with accepted metrology practices.

Voltage Specifications

Voltage Channel Maximum Capacitive Loading for Output Stability

The voltage output will remain stable with 100 nF load but may not be able to drive that capacitance at all voltage/frequency/harmonic combinations due to burden current limitations.

Voltage Range Limits and Burden

Full Range (FR)	23 V	45 V	90 V	180 V	360 V	650 V [4]	1008 V
Max peak [1][2]	32.5 V	63.6 V	127.2 V	254.5 V	509 V	919 V	1425 V
Maximum Burden (peak current) [3]	1 A	1 A	1 A	1 A	1 A	1 A	71 mA
Maximum Burden (RMS current) [3]	500 mA	500 mA	500 mA	250 mA	150 mA	110 mA	60 mA

[1] These values apply to sinusoidal, distorted and modulated wave-shapes.

[2] Voltage harmonic phase angle significantly affects the peak value of a non-sinusoidal waveform.

[3] To achieve specifications in 4-wire sense, resistance in the sense lead must be less than 1 Ω and resistance in the power leads less than 1.5 Ω.

[4] 6105A and 6101B only.

[5] The peak current cannot be sustained and is dependent on the voltage level at which it is requested. It will not be possible to achieve this current when the output is at 0 V but it will be achievable as the voltage approaches the peak level of the waveform. High peak current capability is provided to drive meters that take pulses of current from the signal.

Voltage Sine Amplitude Specifications

Ranges	Frequency	Voltage [5]	6105A & 6106A 1-Year Accuracy, tcal [4] ±5 °C ± (ppm of output + mV) [1]		6100B & 6101B 1-Year Accuracy, tcal [4] ±5 °C ± (ppm of output + mV) [1]		6100B, 6101B, 6105A & 6106A Open Loop 24-Hour Stability ± (ppm of output + mV) [2][3]	
1.0 V - 23 V	45 Hz - 65 Hz	15 V - 17 V	42	0	112	1	75	0.8
		1.0 V - 23 V	42	0.2				
	16 Hz - 850 Hz	1.0 V - 23 V	60	0.2				
3 V - 45 V	45 Hz - 65 Hz	28 V - 32 V	42	0	112	2	75	0.8
		3 V - 45 V	42	0.4				
	16 Hz - 850 Hz	3 V - 45 V	60	0.4				
6.3 V - 90 V	45 Hz - 65 Hz	56 V - 64 V	42	0	112	2.2	75	0.8
		6.3 V - 90 V	42	0.8				
	16 Hz - 850 Hz	6.3 V - 90 V	60	0.8				
13 V - 180 V	45 Hz - 65 Hz	110 V - 128 V	44	0	112	4.4	75	1.5
		13 V - 180 V	44	1.6				
	16 Hz - 850 Hz	13 V - 180 V	60	1.6				
25 V - 360 V	45 Hz - 65 Hz	215 V - 246 V	44	0	112	8.8	75	3
		25 V - 360 V	60	3.2				
	16 Hz - 850 Hz	25 V - 360 V	61	3.2				
46 V – 650 V	45 Hz - 65 Hz	425 V - 490 V	44	0	-	-	75	6
		46 V - 650 V	60	5.8				
	16 Hz - 850 Hz	46 V - 650 V	61	5.8				
70 V - 1008 V	45 Hz - 65 Hz	740 V - 850 V	44	0	150	26	75	10
		70 V - 1008 V	60	10				
	16 Hz - 850 Hz	70 V - 1008 V	61	10				

[1] Four-wire sense only, for two-wire operation, add an additional voltage = 0.3 Ω x maximum burden current to the accuracy specification.

[2] For ±1 °C and constant load and connection conditions.

[3] When Flicker, Fluctuating harmonics, Dip/Swell or Interharmonics are applied, Open Loop Stability specification must be added to the 1-year accuracy specification as described in "Open and Closed Loop Operation".

[4] tcal = temperature of last calibration.

[5] Output levels less than the range minimum can be set but are not specified.

Voltage DC and Harmonic Amplitude Specifications

Range	Output [4][5]	Frequency	6105A & 6106A 1-Year Accuracy, tcal [4] ±5 °C ±(ppm of output + mV) [1][6]		6100B & 6101B 1-Year Accuracy, tcal [4] ±5 °C ±(ppm of output + mV) [1][6]		Open Loop 24-Hour Stability ± (ppm of output + mV) [2][3]	
1.0 V - 23 V	0 V - 11.5 V	DC	91	2	122	5	75	1.8
	0 V - 6.9 V	16 Hz - 850 Hz	58	1	122	1	75	0.8
		850 Hz - 6 kHz	451	1	512	1	150	0.8
3 V - 45 V	0 V - 22.5 V	DC	91	4	122	10	75	3.3
	0 V - 13.5 V	16 Hz - 850 Hz	58	2	122	2	75	0.8
		850 Hz - 6 kHz	451	2	512	2	150	0.8
6.3 V - 90 V	0 V - 45 V	DC	91	8	122	24	75	8
	0 V - 27 V	16 Hz - 850 Hz	60	2.2	122	2.2	75	0.8
		850 Hz - 6 kHz	451	2.2	512	2.2	150	0.8
13 V - 180 V	0 V - 90 V	DC	91	16	122	50	75	15
	0 V - 54 V	16 Hz - 850 Hz	60	4.4	122	4.4	75	1.5
		850 Hz - 6 kHz	451	4.4	512	4.4	150	1.5
25 V - 360 V	0 V - 180 V	DC	91	32	122	100	75	30
	0 V - 108 V	16 Hz - 850 Hz	60	12	122	12	75	3
		850 Hz - 6 kHz	451	12	512	12	150	3
46 V - 650 V	0 V - 325 V	DC	92	60	-	-	75	65
	0 V - 195 V	16 Hz - 850 Hz	61	22	-	-	75	6
		850 Hz - 6 kHz	451	22	-	-	150	6
70 V - 1008 V	0 V - 504 V	DC	92	100	166	300	75	100
	0 V - 302 V	16 Hz - 850 Hz	61	33	166	33	75	10
		850 Hz - 6 kHz	451	33	524	33	150	10

[1] Four-wire sense only, for two-wire operation, add an additional voltage = 0.3 Ω x maximum burden current to the accuracy specification.

[2] For ±1 °C and constant load and connection conditions.

[3] When Flicker, Fluctuating harmonics, Dip/Swell or Interharmonics are applied, "Open loop" stability specification must be added to the 1-year accuracy specification as described in "Open and Closed Loop Operation".

[4] These specifications are only applicable if the combined voltage rms output is greater than the range minimum. If the combined output is below the range minimum the output is not specified.

[5] The maximum value for a single harmonic (2nd to 100th) below 2850 Hz is 30 % of range. See "Amplitude/Frequency Limits" for profile above 2850 Hz.

[6] tcal = temperature of last calibration.

Voltage Distortion and Noise

Range and Frequency		Maximum Harmonic Distortion [1] Either:				Non-harmonic Noise Floor (relative to full range)	
Full Range	Frequency	the largest of		or the largest of		16 Hz - 4 MHz	
		dB	Volts	% Setting	% Range	dB	%
23 V	16 Hz - 850 Hz	-76	480 µV	0.016	0.003	-66	0.05
	850 Hz - 6 kHz	-52	2.4 mV	0.25	0.015	-66	0.05
45 V	16 Hz - 850 Hz	-76	990 µV	0.016	0.003	-70	0.032
	850 Hz - 6 kHz	-52	5.0 mV	0.25	0.015	-70	0.032
90 V	16 Hz - 850 Hz	-76	2.3 mV	0.016	0.003	-72	0.025
	850 Hz - 6 kHz	-52	11 mV	0.25	0.015	-72	0.025
180 V	16 Hz - 850 Hz	-76	5.0 mV	0.016	0.003	-76	0.016
	850 Hz - 6 kHz	-52	25 mV	0.25	0.015	-76	0.016
360 V	16 Hz - 850 Hz	-76	10 mV	0.016	0.003	-66	0.05
	850 Hz - 6 kHz	-52	50 mV	0.25	0.015	-66	0.05
650 V	16 Hz - 850 Hz	-76	20 mV	0.016	0.003	-60	0.1
	850 Hz - 6 kHz	-52	100 mV	0.25	0.015	-60	0.1
1008 V	16 Hz - 850 Hz	-76	30 mV	0.016	0.003	-60	0.1
	850 Hz - 6 kHz	-52	151 mV	0.25	0.015	-60	0.1

[1] dB harmonic distortion increases linearly between 850 Hz and 6 kHz.

Current Range Limits

Full Range (FR)	0.25 A	0.5 A	1 A	2 A	5 A	10 A	21 A	50 A	80 A
Max Peak [1][2]	0.353 A	0.707 A	1.414 A	2.828 A	7.07 A	14.14 A	29.7 A	70.7	113 A
Maximum Compliance Voltage at FR (Vpk) [3][4]	14 V	14 V	14 V	14 V	14 V	14 V	12.5 V	3 V	2 V
Maximum Inductive Load, Hi Bandwidth [5]	300 µH	300 µH	300 µH	300 µH	300 µH	30 µH	30 µH	30 µH	30 µH
Maximum Inductive Load, Lo Bandwidth [5][6]	2 mH	2 mH	1 mH	1 mH	500 µH	360 µH	500 µH	250 µH	250 µH

[1] These values apply to sinusoidal, distorted and modulated wave-shapes.

[2] Current harmonic phase angle significantly affects the peak value of a non-sinusoidal waveform.

[3] Above 450 Hz, the instrument will drive current outputs that develop maximum compliance voltage across the load, but an “adder” to the accuracy specification in “Current DC and Harmonic Amplitude Specifications” and “Current Distortion and Noise” may be required. Calculation of the “adders” is described below.

[4] Compliance voltage at the end of connecting leads will be reduced by the IR drop in the cables.

[5] The current output will remain stable with the inductive loads shown but may not be able to drive that inductance at all current/frequency/harmonic combinations due to voltage burden limitations. The inductive load due to connecting cables may be decreased by reducing their loop area, for example, by tying the cables together or shortening the cables.

[6] In low bandwidth mode maximum frequency is 1.5 kHz.

Load Regulation Specification “adder”

The finite output impedance of the current amplifier causes a “load regulation” effect that must be taken into consideration. Let V_F = the peak voltage developed across the load due to current I_F at frequency F. Let I_{FR} be the maximum current and V_{max} the maximum compliance peak voltage for the range in use.

If $V_F/V_{max} \leq I_F/I_{FR}$ no specification adder is required. Otherwise, the adder is calculated:

$$\text{if } V_F/V_{max} > I_F/I_{FR}, \text{ add: } \frac{I_{FR} \times F \times V_F}{20 \times V_{max}} \mu A$$

Example: The output is a 800 Hz, 0.5 A rms sine wave on the 5 A range. The 6100B current specification from “Current Sine Amplitude Specifications” is:

139 ppm + 120 µA = 70 µA + 120 µA

The voltage across the output is 6 V peak and maximum compliance is 14 V, for example, $V_P/V_{max} > I_P/I_{FR}$. The "adder" is:

$$\frac{5\times 800\times 6}{20\times 14} = 85 \;\; \mu A$$

The current specification becomes:

70 µA + 120 µA + 85 µA = 275 µA

Current Sine Amplitude Specifications

Range (Amps)	Frequency	Current (Amps) [4]	6105A & 6106A 1-Year Accuracy, tcal [3] ±5 °C ±(ppm of output + µA)		6100B & 6101B 1-Year Accuracy, tcal [3] ±5 °C ±(ppm of output + µA)		Open Loop 24-Hour Stability ±(ppm of output + µA) [1][2]	
0.25 A	45 Hz - 65 Hz	0.1 A - 0.25 A	46	2.5	139	6	75	3
		0.25 A	46	1.5	130	6	75	3
	16 Hz - 850 Hz	0.01 A - 0.1 A	60	5	139	6	75	3
		0.1 A - 0.25 A	60	5	139	6	75	3
0.5 A	45 Hz - 65 Hz	0.2 A - 0.5 A	46	5	139	12	75	5
		0.5 A	46	3	130	12	75	5
	16 Hz - 850 Hz	0.05 A - 0.2 A	61	10	139	12	75	5
		0.2 A - 0.5 A	61	10	139	12	75	5
1 A	45 Hz - 65 Hz	0.4 A - 1.0 A	47	10	139	24	75	10
		1 A	47	6	130	24	75	10
	16 Hz - 850 Hz	0.1 A - 0.4 A	61	20	139	24	75	10
		0.4 A - 1 A	61	20	139	24	75	10
2 A	45 Hz - 65 Hz	0.8 - 2 A	46	20	139	48	75	20
		2 A	46	12	130	48	75	20
	16 Hz - 850 Hz	0.2 A - 0.8 A	61	40	139	48	75	20
		0.8 A - 2 A	61	40	139	48	75	20
5 A	45 Hz - 65 Hz	2 - 5 A	49	50	139	120	75	50
		5 A	49	30	130	120	75	50
	16 Hz - 850 Hz	0.5 A - 2 A	64	100	139	120	75	50
		2 A - 5 A	64	100	139	120	75	50
10 A	45 Hz - 65 Hz	4 - 10 A	49	100	191	240	75	50
		10 A	49	60	164	240	75	50
	16 Hz - 850 Hz	1 A - 4 A	65	200	191	240	75	100
		4 A - 10 A	65	200	191	240	75	100
21 A	45 Hz - 65 Hz	8 A - 21 A	49	200	213	720	75	300
		21 A	49	120	189	720	75	300
	16 Hz - 850 Hz	2 A - 8 A	69	400	213	720	75	300
		8 A - 21 A	69	400	213	720	75	300
50 A	45 Hz - 65 Hz	20 A - 50 A	49	500	213	1800	500	750
		50 A	49	300	189	1800	500	750
	40 Hz - 850 Hz	3.2 A - 20 A	74	1000	213	1800	500	750
		20 A - 50 A	74	1000	213	1800	500	750

80 A	40 Hz - 450 Hz	8 A - 32 A	106	2800	265	2800	1000	1200
		32 A - 80 A	106	2800	250	2800	1000	1200
	450 Hz - 850 Hz	8 A - 32 A	112	2800	300	2800	1000	1200
		32 A - 80 A	118	2800	280	2800	1000	1200

[1] For ±1 °C and constant load and connection conditions.

[2] When Flicker, Fluctuating harmonics, Dip/Swell or Interharmonics are applied, "Open loop" stability specification must be added to the 1-year accuracy specification as described in "Open and Closed Loop Operation".

[3] tcal = temperature of last calibration.

[4] Output levels less than the range minimum can be set but are not specified.

[5] Settling time (TS) of 21 A, 50 A, and 80 A ranges depends on rms output as a proportion of full range and can be calculated from: TS = %FR2 x 180 seconds. Settling magnitude will not exceed 50 ppm at FR.

Current DC and Harmonic Amplitude Specifications

Range	Current [4]	Frequency	6105A & 6106A 1-Year Accuracy, tcal [3] ±5 °C ±(ppm of output + µA)		6100B & 6101B 1-Year Accuracy, tcal [3] ±5 °C ±(ppm of output + µA)		Open Loop 24-Hour Stability ±(ppm of output + µA) [1][2]	
0.01 A - 0.25 A	0 A - 0.125 A	DC	89	25	139	75	100	11
	0 A - 0.075 A	16 Hz - 850 Hz	61	5	139	6	75	3
		850 Hz - 6 kHz	400	5	400	6	150	3
0.05 A - 0.5 A	0 A - 0.25 A	DC	89	50	139	150	100	22
	0 A - 0.15 A	16 Hz - 850 Hz	61	10	139	12	75	5
		850 Hz - 6 kHz	400	10	400	12	150	5
0.1 A -1 A	0 A - 0.5 A	DC	89	100	139	300	100	45
	0 A - 0.3 A	16 Hz - 850 Hz	61	20	139	24	75	10
		850 Hz - 6 kHz	400	20	400	24	150	10
0.2 A - 2 A	0 A - 1 A	DC	89	200	139	600	100	90
	0 A - 0.6 A	16 Hz - 850 Hz	61	40	182	48	75	20
		850 Hz - 6 kHz	400	40	400	48	150	20
0.5 A - 5 A	0 A - 2.5 A	DC	89	500	139	1500	100	225
	0 A - 1.5 A	16 Hz - 850 Hz	61	100	139	120	75	50
		850 Hz - 6 kHz	400	100	400	120	150	50
1 A - 10 A	0 A - 5 A	DC	89	1000	191	3000	100	450
	0 A - 3 A	16 Hz - 850 Hz	64	200	191	240	75	100
		850 Hz - 6 kHz	400	200	400	240	150	100
2 A - 21 A	0 A - 10 A	DC	90	2000	191	6000	100	900
	0 A - 6 A	16 Hz - 850 Hz	65	400	191	720	75	300
		850 Hz - 6 kHz	400	400	400	720	150	300
5 A - 50 A	0 A - 15 A	16 Hz - 850 Hz	69	1000	250	2800	500	750
		850 Hz - 3 kHz	400	1000	400	2800	750	1200
8 A - 80 A	0 A - 24 A	16 Hz - 850 Hz	112	2000	265	2800	500	1200
		850 Hz - 3 kHz	400	2000	400	2800	750	1200

[1]	For ±1 °C and constant load and connection conditions.
[2]	When Flicker, Fluctuating harmonics, Dip/Swell or Interharmonics are applied, "Open loop" stability specification must be added to the 1-year accuracy specification as described in "Open and Closed Loop Operation".
[3]	tcal = temperature of last calibration.
[4]	These specifications are only applicable if the combined voltage rms output is greater than the range minimum. If the combined output is below the range minimum the output is not specified.
[5]	The maximum value for a single harmonic (2nd to 100th) below 2850 Hz is 30 % of range. See "Amplitude/Frequency Limits" for profile above 2850 Hz.

Current Distortion and Noise

Range and Frequency		Maximum Harmonic Distortion [1] Either:				Non-Harmonic Noise Floor (relative to full range)	
Full Range	Frequency	the largest of		or the largest of		16 Hz - 4 MHz	
		dB	Amps	% Setting	% Range	dB	%
0.25 A	16 Hz - 850 Hz	-80	7.5 µA	0.01	0.003	-50	0.316
	850 Hz - 6 kHz	-60	25 µA	0.1	0.01	-50	0.316
0.5 A	16 Hz - 850 Hz	-80	15 µA	0.01	0.003	-60	0.100
	850 Hz - 6 kHz	-60	50 µA	0.1	0.01	-60	0.100
1 A	16 Hz - 850 Hz	-80	30 µA	0.01	0.003	-60	0.100
	850 Hz - 6 kHz	-60	100 µA	0.1	0.01	-60	0.100
2 A	16 Hz - 850 Hz	-80	60 µA	0.01	0.003	-65	0.056
	850 Hz - 6 kHz	-60	200 µA	0.1	0.01	-65	0.056
5 A	16 Hz - 850 Hz	-80	150 µA	0.01	0.003	-65	0.056
	850 Hz - 6 kHz	-60	500 µA	0.1	0.01	-65	0.056
10 A	16 Hz - 850 Hz	-80	300 µA	0.01	0.003	-50	0.316
	850 Hz - 6 kHz	-60	1.0 mA	0.1	0.01	-50	0.316
21 A	16 Hz - 850 Hz	-80	600 µA	0.01	0.003	-50	0.316
	850 Hz - 6 kHz	-60	2.0 mA	0.1	0.01	-50	0.316
50 A	16 Hz - 850 Hz	-80	2.0 mA	0.01	0.003	-50	0.316
	850 Hz - 6 kHz	-60	5.0 mA	0.1	0.01	-50	0.316
80 A	16 Hz - 850 Hz	-80	2.4 mA	0.1	0.003	-70	0.032
	850 Hz - 3 kHz	-60	8.0 mA	0.1	0.01	-70	0.032

[1] dB harmonic distortion increases linearly between 850 Hz and 6 kHz.

Voltage from the Current Terminals

Range Limits and Impedances

Full Range (FR)	0.25 V	1.5 V	10 V
Max Peak [1][2]	0.353 V	2.121 V	14.14 V
Source Impedance	1 Ω	6.67 Ω	40.02 Ω
Minimum load impedance to maintain specification [3]	40 kΩ	260 kΩ	1.5 MΩ

[1] These values apply to sinusoidal, distorted and modulated wave shapes.
[2] Harmonic phase angle significantly affects the peak value of a non-sinusoidal waveform.
[3] For a load less than specified, calculate error from parallel combination of source and load impedance.

Sine Specifications

Range	Frequency	Output Component [3]	6105A & 6106A 1-Year Accuracy, tcal [4] ±5 °C ± (ppm of output + µV)		6100B & 6101B 1-Year Accuracy, tcal [4] ±5 °C ± (ppm of output + µV)		Open Loop 24-Hour Stability ± (ppm of output + µV) [1][2]	
0.05 V - 0.25 V	45 Hz - 65 Hz	0.1 V - 0.25 V	73	10	200	10	90	15
	16 Hz - 850 Hz	0.05 V - 0.25 V	82	10	200	10	90	15
0.15 V - 1.5 V	45 Hz - 65 Hz	0.6 V - 1.5 V	53	50	200	50	75	25
	16 Hz - 850 Hz	0.6 V - 1.5 V	66	50	200	50	75	25
1 V - 10 V	45 Hz - 65 Hz	4 V - 10 V	52	200	200	200	75	150
	16 Hz - 850 Hz	4 V - 10 V	66	200	200	200	75	150

[1] For ±1 °C and constant load and connection conditions.
[2] When Flicker, Fluctuating harmonics, Dip/Swell or Interharmonics are applied, "Open loop" stability specification must be added to the 1-year accuracy specification as described in "Open and Closed Loop Operation".
[3] Output levels less than the range minimum can be set but are not specified.
[4] tcal = temperature of last calibration.

DC and Harmonic Amplitude Specifications

Range	Output [4][5]	Frequency	6105A & 6106A 1-Year Accuracy, tcal [4] ±5 °C ± (ppm of output + µV) [5]		6100B & 6101B 1-Year Accuracy, tcal [4] ±5 °C ± (ppm of output +µV) [5]		Open Loop Stability ± (ppm of output + µV) per Hour [2][3]	
0.05 V - 0.25 V	0 V - 0.125 V	DC	91	35	200	35	100	15
	0 V - 0.075 V	16 Hz - 850 Hz	82	10	200	10	60	15
		850 Hz - 6 kHz	400	30	1000	30	150	15
0.15 V - 1.5 V	0 V - 0.75 V	DC	93	210	200	210	100	75
	0 V - 0.45 V	16 Hz - 850 Hz	66	35	200	50	50	25
		850 Hz - 6 kHz	400	50	1000	50	150	25
1 V - 10 V	0 V - 5 V	DC	93	1000	200	1000	100	450
	0 V - 3 V	16 Hz - 850 Hz	65	200	200	200	50	150
		850 Hz - 6 kHz	400	300	1000	300	150	150

[1] tcal = temperature of last calibration.
[2] For ±1 °C and constant load and connection conditions.
[3] When Flicker, Fluctuating harmonics, Dip/Swell or Interharmonics are applied, "Open loop" stability specification must be added to the 1-year accuracy specification as described in "Open and Closed Loop Operation".
[4] These specifications are only applicable if the combined voltage rms output is greater than the range minimum. If the combined output is below the range minimum the output is not specified.
[5] The maximum value for a single harmonic (2nd to 100th) below 2850 Hz is 30 % of range. See "Amplitude/Frequency Limits" for profile above 2850 Hz.

Voltage from Current Terminals, Distortion and Noise

Range and Frequency		Maximum Harmonic Distortion [1] Either				Non-harmonic Noise Floor (relative to full range)	
		the largest of		or the largest of		16 Hz - 4 MHz	
Full Range	Frequency	dB	Volts	% Setting	% Range	dB	%
0.25 V	16 Hz - 850 Hz	-80	2.5 µV	0.010	0.001	-50	0.316
	850 Hz - 6 kHz	-60	25 µV	0.100	0.01	-50	0.316
1.5 V	16 Hz - 850 Hz	-80	15 µV	0.010	0.001	-60	0.100
	850 Hz - 6 kHz	-60	150 µV	0.100	0.01	-60	0.100
10 V	16 Hz - 850 Hz	-80	100 µV	0.010	0.001	-60	0.100
	850 Hz - 6 kHz	-60	1 mV	0.100	0.01	-60	0.100

[1] dB harmonic distortion increases linearly between 50 Hz and 6 kHz.

Current to Voltage Phase Specifications

For Voltage from the Current terminals, use the 0.25 A to 21 A phase specification.

For All Voltage Ranges (23 V - 1008 V)		6105A /6106A Voltage and Current Components >40 % of Range		6100B / 6101B Voltage and Current Components >40 % of Range		Voltage or Current Component 0.5 % - 40 % of Range [5]	
Current Range	Frequency	1-Year Accuracy, tcal [4] ±5 °C [1][2]	Open Loop 24-Hour Stability [2][3]	1-Year Accuracy, tcal [4] ±5 °C [1][2]	Open Loop 24-Hour Stability [2][3]	1-Year Accuracy, tcal ±5 °C [1][2]	Open Loop 24-Hour Stability [2][3]
0.25 A - 21 A	45 Hz - 65 Hz	0.0023 °	0.0002 °	0.003 °	0.0002 °	0.010 °	0.001 °
	16 Hz - 69 Hz	0.003 °	0.0002 °	0.003 °	0.0002 °	0.010 °	0.001 °
	69 Hz - 180 Hz	0.007 °	0.0002 °	0.009 °	0.0002 °	0.017 °	0.002 °
	180 Hz - 450 Hz	0.018 °	0.0005 °	0.023 °	0.0005 °	0.050 °	0.005 °
	450 Hz - 850 Hz	0.033 °	0.0008 °	0.043 °	0.0008 °	0.070 °	0.007 °
	850 Hz - 3 kHz	0.115 °	0.0010 °	0.150 °	0.0010 °	0.200 °	0.020 °
	3 kHz - 6 kHz	0.230 °	0.0010 °	0.300 °	0.0010 °	0.450 °	0.045 °
21 A - 50 A	45 Hz - 65 Hz	0.0023 °	0.0002 °	0.004 °	0.0003 °	0.010 °	0.001 °
	16 Hz - 69 Hz	0.003 °	0.0003 °	0.004 °	0.0003 °	0.010 °	0.001 °
	69 Hz - 180 Hz	0.007 °	0.0003 °	0.012 °	0.0003 °	0.017 °	0.002 °

	180 Hz - 450 Hz	0.018 °	0.0005 °	0.030 °	0.0005 °	0.050 °	0.005 °
	450 Hz - 850 Hz	0.033 °	0.0010 °	0.050 °	0.0010 °	0.070 °	0.007 °
	850 Hz - 3 kHz	0.115 °	0.0015 °	0.200 °	0.0015 °	0.200 °	0.020 °
	3 kHz - 6 kHz	0.230 °	0.0025 °	0.300 °	0.0025 °	0.450 °	0.045 °
20 A - 80 A	45 Hz - 65 Hz	0.003 °	0.0002 °	0.004 °	0.0005 °	0.010 °	0.001 °
	16 Hz - 69 Hz	0.003 °	0.0005 °	0.004 °	0.0005 °	0.016 °	0.002 °
	69 Hz - 180 Hz	0.008 °	0.0005 °	0.012 °	0.0005 °	0.028 °	0.003 °
	180 Hz - 450 Hz	0.025 °	0.0010 °	0.030 °	0.0010 °	0.080 °	0.008 °
	450 Hz - 850 Hz	0.050 °	0.0015 °	0.050 °	0.0015 °	0.100 °	0.010 °
	850 Hz - 3 kHz	0.250 °	0.0025 °	0.200 °	0.0025 °	0.300 °	0.030 °

[1] Current phase angle errors are relative to the voltage channel of the same phase. For example, L2 current is relative to L2 voltage.
[2] Phase angle contribution to power accuracy varies with set phase angle see "Power Specifications" below.
[3] For constant load and connection conditions.
[4] tcal = temperature of last calibration.
[5] Phase performance at less than 0.5 % of full range degrades as output components approach the resolution limit of the digital feedback system.

Multi-Phase Operation

Voltage to Voltage Phase Specifications

For All Voltage Ranges (23 V - 1008 V)	6105A /6106A Voltage and Current Components >40 % of Range		6100B / 6101B Voltage and Current Components >40 % of Range		Voltage or Current Component 0.5 % - 40 % of Range [5]	
Frequency	1-Year Accuracy, tcal [4] ±5 °C [1][2]	Stability per hour [2][3]	1-Year Accuracy, tcal [4] ±5 °C [1][2]	Stability per hour [2][3]	1-Year Accuracy, tcal ±5 °C [1][2]	Stability per hour [2][3]
16 Hz - 69 Hz	0.005 °	0.0002 °	0.005 °	0.0002 °	0.010 °	0.001 °
69 Hz - 180 Hz	0.007 °	0.0002 °	0.007 °	0.0002 °	0.017 °	0.002 °
180 Hz - 450 Hz	0.025 °	0.0005 °	0.025 °	0.0005 °	0.050 °	0.005 °
450 Hz - 850 Hz	0.043 °	0.0008 °	0.050 °	0.0008 °	0.070 °	0.007 °
850 Hz - 3 kHz	0.150 °	0.0010 °	0.170 °	0.0010 °	0.200 °	0.020 °
3 kHz - 6 kHz	0.300 °	0.0010 °	0.350 °	0.0015 °	0.450 °	0.045 °

[1] Current phase angle errors are relative to the voltage channel of the same phase. For example, L2 current is relative to L2 voltage.
[2] Phase angle contribution to power accuracy varies with set phase angle see "Power Specifications" below.
[3] For constant load and connection conditions.
[4] tcal = temperature of last calibration.
[5] Phase performance at less than 0.5 % of full range degrades as output components approach the resolution limit of the digital feedback system.

Energy Specifications

Pulse Inputs

Max frequency	5 MHz (100 Hz for debounced inputs)
Min pulse width	100 ns
Max counts per channel	232-1 (4,294,967,295)

Pulse and Gate Inputs

Input Low level max	1 V
Input High level min	3 V
Internal pull-up values	135 Ω and 940 Ω to 4.5 V nominal
	(Approximately equivalent to 150 Ω/1k Ω to 5 V nominal)
Max input voltage	28 V (clamped @ 30 V approximately) [1]
Min input voltage	0 V (clamped @ -0.5 V approximately) [1]

Pulse Output

Drive	Open-collector with optional internal 470 Ω pull-up
Frequency range	1 mHz – 5 MHz
Frequency accuracy	± (10 ppm + 100 nHz)
External pull-up voltage	30 V MAX (clamped) [1]
Sink current	150 mA MAX

Gate Output

Drive	Open-drain
Internal Pull-up	As Gate-Input
External pull-up voltage	30 V MAX (clamped) [1]
Sink current	1 A MAX

[1] Input/Output protection: 30 V / -0.5V (approximately) clamped, up to 120 mA per signal or 300 mA maximum total all signals.

Accuracy

Counted/Timed timing accuracy	± (10 ppm + 100 ns) [2]
Gated mode accuracy	± (10 ppm + 100 ns) [2]
Packet mode accuracy (ppm) [3]	± (output power (ppm) + 10 ppm + 110,000/Test Duration (secs))

[2] Accuracy depends on the period between the application of power (pressing the OPER key) and the gate signal becoming active being greater than 2 seconds.

[3] Specification not valid if "Soft Start" is enabled.

Test Duration

Maximum test duration	1000 hours

Power Specifications

The example power specifications below are only valid for rms values greater than 40 % of range for voltage and current and frequency less than 450 Hz. They are not valid when any of: Flicker, Fluctuating harmonics, Dip/Swell or Interharmonics are applied to the voltage or current channel of that 6100B.

6105A and 6106A Sinusoidal Power Accuracy at 45 Hz to 65 Hz; Power Factor 1.0 (ppm) [1]

Current	Power with Current at 90 % of Range			Power with Current at 50 % of Range		
	Voltage at 62 % to 70 % of Range		650 V & 1008 V Ranges; 70 % to 75 %	Voltage at 7 % to 100 % of Range		650 V & 1008 V Ranges; 70 % to 75 %
	23 V to 90 V	180 V & 360 V		23 V to 90 V	180 V & 360 V	
0 A to 2 A	62	64	64	72	74	74
5 A to 50 A	65	66	66	74	75	75
80 A	147	148	148	181	181	181

[1] For Energy specification add 1 ppm

Note: 100 ppm = 0.01 %

6105A and 6106A Sinusoidal Power Accuracy at 45 Hz to 65 Hz; Power Factor 0.5 (ppm) [1]

Current	Power with Current at 90 % of Range			Power with Current at 50 % of Range		
	Voltage at 62 % to 70 % of Range		650 V & 1008 V Ranges; 70 % to 75 %	Voltage at 7 % to 100 % of Range		650 V & 1008 V Ranges; 70 % to 75 %
	23 V to 90 V	180 V & 360 V		23 V to 90 V	180 V & 360 V	
0 A to 5 A	93	94	94	100	101	101
10 A to 50 A	95	96	96	102	102	102
80 A	163	163	163	194	194	194

[1] For Energy specification add 1 ppm

Note: 100 ppm = 0.01 %

FLUKE®
Calibration

6100B and 6101B Sinusoidal Power Accuracy at 45 Hz to 65 Hz; Power Factor 1.0 (ppm) [1]

Current	Power with Current at 90 % of Range		Power with Current at 50 % of Range	
	23 V to 360 V Ranges; 62 % to 70 % Range	1008 V Range; 740 V to 850 V	23 V to 360 V Ranges; 62 % to 70 % Range	1008 V Range; 740 V to 850 V
0 A to 2 A	236	239	252	239
5 A to 50 A	236	239	252	239
80 A	322	339	404	417

[1] For Energy specification add 1 ppm
Note: 100 ppm = 0.01 %

6100B and 6101B Sinusoidal Power Accuracy at 45 Hz to 65 Hz; Power Factor 0.5 (ppm) [1]

Current	Power with Current at 90 % of Range		Power with Current at 50 % of Range	
	23 V to 360 V Ranges; 62 % to 70 % Range	1008 V Range; 740 V to 850 V	23 V to 360 V Ranges; 62 % to 70 % Range	1008 V Range; 740 V to 850 V
0 A to 5 A	246	249	262	249
10 A to 50 A	246	249	262	249
80 A	329	346	409	423

[1] For Energy specification add 1 ppm
Note: 100 ppm = 0.01 %

6105A and 6106A Sinusoidal Power Accuracy with 20 % THD at Power Factor 1.0 (ppm) [1]

Accuracy Depends on Harmonic Order and Amplitudes

Current	Power with Current at 90 % of Range			Power with Current at 50 % of Range		
	Voltage at 62 % to 70 % of Range			Voltage at 7 % to 100 % of Range		650 V & 1008 V Ranges; 70 % to 75 %
	23 V to 90 V	180 V & 360 V	650 V & 1008 V Ranges; 70 % to 75 %	23 V to 90 V	180 V & 360 V	
0 A to 5 A	97	98	98	103	105	105
10 A to 50 A	98	99	99	105	105	105
80 A	165	165	165	196	196	196

[1] For Energy specification add 1 ppm
Note: 100 ppm = 0.01 %

6100B and 6101B Non-sinusoidal Power Accuracy with 20 % THD at Power Factor 1.0 (ppm) [1]

Accuracy Depends on Harmonic Order and Amplitudes

V Range	Power with Current at 90 % of Range		Power with Current at 50 % of Range	
Current	23 V to 360 V; 62 % to 70 % Range	1008 V Range; 740V to 850 V	23 V to 360 V Ranges; 62 % to 70 % Range	1008 V Range; 740 V to 850 V
0 A to 5 A	242	255	258	255
10 A to 50 A	242	255	258	255
80 A	326	350	408	426

[1] For Energy specification add 1 ppm
Note: 100 ppm = 0.01 %

Voltage and Current Sinusoidal and Rectangular Modulation Flicker Specification

Setting range	±30 % of set value within range values (60 % ΔV/V)
Flicker modulation depth accuracy	0.025 %

Modulation depth setting resolution		0.001 %
Shape of modulation envelope		Rectangular, Square or Sinusoidal
Duty cycle (shape = rectangular)		0.01 % to 99.99 %; accuracy = ±31 µs
Modulation units Either:	Frequency or Changes per minute	0.5 Hz to 40 Hz
		1.0 CPM to 4800 CPM
Modulating frequency accuracy [1][2]		<0.13 % (1 CPM to 4800 CPM)

[1] Rectangular modulation accuracy is ±{(10 + 31 x modulating frequency) ppm + 10 µHz}

[2] Sine modulation accuracy is ±(50 ppm +10 µHz)

Pst and Pinst Indication Accuracy

P_{st} and P_{inst} values are from IEC 61000-4-15, (amendment 1). Note that P_{st} and P_{inst} indications are only valid for 230 V and 120 V, 50 Hz and 60 Hz. P_{st} values are not valid for the current channel.

Voltage Setting	P_{st} Indication Accuracy
220 V - 240 V	±0.25 %
115 V - 125 V	±0.25 %

Note that long term flicker (P_{lt}) can be simulated either by a steady P_{st} over a suitable period, or by changing P_{st} and calculating P_{lt} from:

$$P_{lt} = \sqrt[3]{\frac{\sum_{i=1}^{N} P_{sti}^{3}}{N}}$$

where P_{sti} (i=1,2,3, ...) are different consecutive readings of P_{st}. See IEC61000-4-15 for details.

Other Flicker Modes

Extended Flicker functions are provided. The accuracy of these signals is better than 1 %:

- Frequency Changes
- Distorted voltage with multiple zero crossings
- Harmonics with side band
- Phase jumps
- Rectangular voltage changes with duty ratio

Fluctuating Harmonic Specifications

Fluctuating harmonics are available on voltage and current outputs. Fluctuating Harmonics are not available on a voltage or current channel if Flicker is already enabled on that channel.

Number of harmonics to fluctuate	Any number from 0 to all set harmonics can fluctuate
Modulation depth setting range [1]	0 % to 100 % of nominal harmonic voltage
Fluctuation accuracy (0 % to ±30 % modulation)	±0.025 %
Modulation depth setting resolution	0.001 %
Shape	Rectangular or Sinusoidal
Duty cycle (shape = rectangular)	0.1 % to 99.99 %
Modulating Frequency range	0.008 Hz to 30 Hz
Sine modulating frequency accuracy	±(50 ppm + 10 µHz)
Rectangular modulating frequency accuracy	<1300 ppm [2]
Modulating Frequency setting resolution	0.001 Hz

[1] Fluctuation accuracy is not specified for modulation depth >±30 %.

[2] Accuracy is ±{(50 + 31 x modulating frequency) ppm + 10 µHz}.

Interharmonic Specifications

Interharmonics are available on voltage and current outputs

Frequency accuracy	±500 ppm
Amplitude accuracy 16 Hz to <6 kHz	±1 %
Amplitude accuracy >6 kHz	4 %
Maximum value of a single interharmonic	The maximum value for an interharmonic <2850 Hz is 30 % of range. See "Amplitude/Frequency Limits" for profile above 2850 Hz.
Frequency range of interharmonic	16 Hz to 9 kHz

Dip/Swell Specifications

Although Dips and Swells are primarily voltage phenomena, the 6100B provides the same facility on its current output.

Trigger-in requirement	TTL falling edge remaining low for 10 µs
Either: Trigger-in delay OR Phase-angle synchronization with respect to channel fundamental frequency zero crossing	0 to 60 s ±31 µs ±180 ° ±31 µs
Dip/Swell Min duration	1 ms
Dip/Swell Max duration	1 minute
Dip Min amplitude	0 % of the nominal output
Swell Max amplitude	The least of full range value and 140 % of the nominal output
Ramp up/down period	Settable 100 µs to 30 s
Optional repeat with delay	0 to 60 s ±31 µs
Starting level amplitude accuracy	±0.025 % of level
Dip/Swell level amplitude accuracy [1]	±0.25 % of level
Trigger out delay	0 to 60 s ±31 µs from start of dip/swell event
Trigger out	TTL falling edge co-incident with end of trigger out delay, remaining low for 10 µs to 31 µs

[1] Accuracy not specified below 10 % of starting level or below the range minimum value.

Determining Non-sinusoidal Waveform Amplitude Specifications

The rms value of the combination of voltage components is:

$V_{RMS}^2 = \sum_{i=1}^{N} V_i^2$ and, assuming symmetrical uncertainties, $u(V)_i$, for each of V_i,

Note that the uncertainties of the components of a 6100B non-sinusoidal voltage (or current) waveform are correlated so must be combined by linear addition.

$$(V_{RMS} + u(V_{RMS}))^2 = \sum_{i=1}^{N} (V_i + u(V_i))^2$$

$$V_{RMS}^2 + 2V_{RMS}u(V_{RMS}) + u^2(V_{RMS}) =$$

$$V_1^2 + 2V_1\, u(V_1) + u^2(V)_1 + V_2^2 + 2V_2\, u(V_2) + u^2(V_2) \ldots V_n^2 + 2V_n\, u(V_n) u^2 V_n$$

But $V_{RMS}^2 = \sum_{i=1}^{N} V_i^2$,

and, where uncertainties are relatively small (as in the 6100B), $u^2 v_i$ components become negligible. The uncertainty of the combined waveform becomes:

$$2V_{RMS}u(V_{RMS}) = 2V_1\, u(V_1) + 2V_2\, u(V_2) \ldots 2V_n\, u(V_n)$$

which simplifies to give u_c as the combined uncertainty:

$$u_c(V_{RMS}) = \sum_{i=1}^{N} c_i u(V_i)$$

where $c_i = \frac{V_i}{V_{RMS}}$ and is known as the sensitivity coefficient.

Non-sinusoidal Voltage Example

The waveform is a 60 Hz, 110 V rms waveform, from the 168 V range, comprising 10 % 95th harmonic, 30 % 3rd harmonic with the remainder contributed by the fundamental frequency. Using the 6100B voltage uncertainty values in "Voltage and Sine Amplitude Specifications" and "Voltage DC and Harmonic Specifications", determine the 1-year accuracy.

3rd Harmonic rms voltage = 0.3 x 110 = 33 V

95th Harmonic rms voltage = 0.1 x 110 = 11 V

Fundamental rms voltage = $\sqrt{(110^2 - 33^2 - 11^2)}$ = 104.3552 V

Accuracy contribution from the fundamental:

112 ppm of output +4.4 mV = (104.3552 x 0.000112) + 0.0044 = 0.011688 + 0.0044 = 0.016088 V

Modified by the sensitivity coefficient = 0.016088 x 104.3552 ÷ 110 = 0.015262 V

Accuracy contribution from the 3rd Harmonic (180 Hz):

122 ppm of 3rd harmonic value +4.4 mV = (0.000122 x 33) + 0.0044 = 0.008426 V

Modified by the sensitivity coefficient = 0.008426 x 33 ÷ 110 = 0.002528 V

Accuracy contribution from the 95th Harmonic (5700 Hz):

512 ppm of 95th harmonic value + 4.4 mV = (0.000512 x 11) + 0.0044 = 0.010032 V

Modified by the sensitivity coefficient = 0.010032 x 11 ÷ 110 = 0. 001003 V

Combining the uncertainties:

Total amplitude uncertainty = 0.015262 + 0.002528 + 0.010032 = 0.018793 V

Voltage Accuracy = 110 ±0.018793 *V*

Apparent Power (S) Accuracy Calculations

For the purpose of calculation of apparent power (S) for non-sinusoidal outputs the following equations are used:

$$S = \sqrt{\sum_n V_n^2 \sum_n I_n^2} \text{ VA}$$

To calculate the accuracy of apparent power (S), the amplitude accuracy specifications of voltage harmonic components must be combined as described in "Determining Non-Sinusoidal Waveform Amplitude Specifications" above. Current components are combined using the same method. As apparent power is the product of two different quantities, uncertainties are conveniently combined using relative values. Note that 6100B voltage and current components are generated independently and are therefore largely uncorrelated.

As $S^2 = V_{RMS}^2 . I_{RMS}^2$;

$$\frac{u_c{}^2(S)}{S^2} = [\frac{u(V_{RMS})}{V_{RMS}}]^2 + [\frac{u(I_{RMS})}{I_{RMS}}]^2$$

where $u_c(S)$ is the combined uncertainty of the apparent Power,

$u(V_{RMS})$ is the uncertainty of the rms voltage and

$u(I_{RMS})$ is the uncertainty of the rms current.

Apparent Power Example

Voltage channel fundamental frequency output is 109 V on the 1 V range at 60 Hz. A 15 V 3rd harmonic has been added. The current channel output is 7 A at 60 Hz on the 10 A range with 3rd and 5th harmonics at 0.7 A and 0.3 A respectively. Phase angles are not relevant to the calculation of apparent power. Voltage uncertainty values are given in "Voltage and Sine Amplitude Specifications" and "Voltage DC and Harmonic Specifications", current uncertainty values are given in "Current Sine Amplitude Specifications" and "Current DC and Harmonic Amplitude Specifications". The accuracy used is that of the 6100B.

The voltage rms value is $\sqrt{109^2 + 15^2} = 110.02727 \ V$

Accuracy contribution from the voltage fundamental:

112 ppm of 109 V + 4.4 mV = (109x0.000112) + 0.0044 = 0.012208 + 0.0044 = 0.016608 V

Modified by the sensitivity coefficient = 0.016608 x 109 ÷ 110.02727 = 0.016453 V

Accuracy contribution from the voltage 3rd harmonic:

122 ppm of 15 V + 4.4 mV = (15x0.000112) + 0.0044 = 0.01830 + 0.0044 = 0.006230 V

Modified by the sensitivity coefficient = 0.006230 x 15 ÷ 110.02727 = 0.000849 V

Combined voltage uncertainty:

$$\frac{u(V_{RMS})}{V_{RMS}} = \frac{0.016453 + 0.000849}{110.02727} = 0.000157$$ (or 157 ppm).

The current rms value is $\sqrt{7^2 + 0.7^2 + 0.3^2} = 7.041307$

Accuracy contribution from the current fundamental:

164ppm of 7 A + 240 µA = (7x0.000164) + 0.000240 = 0.001148 + 0.000240 = 0.001388

Modified by the sensitivity coefficient = 0.001388 x 7 ÷ 7.041307 = 0.001380 A

Accuracy contribution from the current 3rd harmonic:

191 ppm of 0.7 A + 240 µA = (0.7x0.000191) + 0. 000240 = 0.000134 + 0.000240 = 0.000374

Modified by the sensitivity coefficient = 0. 000374 x 0.7 ÷ 7.041307 = 0.000037 A

Accuracy contribution from the current 5th harmonic:

191 ppm of 0.3 A + 240 µA = (0.3x0.000191) + 0. 000240 = 0.000058 + 0.000240 = 0.000297

Modified by the sensitivity coefficient = 0.000297 x 0.3 ÷ 7.041307 = 0.000013 A

Combined current uncertainty:

$$\frac{u(I_{RMS})}{I_{RMS}} = \frac{0.001388 + 0.000037 + 0.000013}{7.041307} = 0.000204$$ (or 204 ppm).

Now, $S^2 = V_{RMS}^2 . I_{RMS}^2 = 110.02727 \times 7.041307 = 774.7358 \ VA$

Apparent Power uncertainty:

$$\frac{u(S)}{S} = \sqrt{[\frac{u(V_{RMS})}{V_{RMS}}]^2 + [\frac{u(I_{RMS})}{I_{RMS}}]^2} = \sqrt{0.000157^2 + 0.000204^2} = 0.0002574$$

giving:

$$u_c(S) = 0.0002574 \times 774.735748 = 0.1994 \ VA$$

Apparent Power Accuracy = 774.7358± 0.1994 VA

Power (P) Accuracy Calculations

Real power is the sum of the products of volt/current/phase-angle at each harmonic frequency.

$$P = \sum V_n I_n \cos \Phi_n$$ Watts

where *n* is the harmonic order of the components.

Calculation of power accuracy uses the same techniques shown previously. The uncorrelated uncertainty components of voltage, current and phase are combined using root sum of squares for each frequency.

$$\frac{u^2(P_f)}{P_f^2} = [\frac{u(V_f)}{V_f}]^2 + [\frac{u(I_f)}{I_f}]^2 + [u(phase_f)]^2$$

where $u(x)$ is the uncertainty of the component x and $phase$ is the phase angle between the current and voltage at frequency f. It is easiest to express each of these contributions as ppm.

The contribution of phase angle accuracy varies with the set phase angle as shown below.

$$u(phase) = 1 - \frac{\cos(\Phi + u(\phi))}{\cos \Phi}$$

where Φ is the set phase angle and $u(\phi)$ is the phase accuracy.

The power uncertainties for each frequency, modified by the appropriate sensitivity coefficient c_i, are then linearly summed to give the combined uncertainty u_c (linearly summed because voltage components are correlated, as are those of current and phase).

$$u_c(P) = \sum_{i=1}^{N} c_i u(P_i)$$

Power Example

Voltage channel output is 109 V on the 180 V range at 60 Hz with 3rd harmonic at 15 V. The voltage 3rd harmonic has 0 ° phase angle relative to the voltage fundamental.

The current channel output is 7 A on the 10 A range at 60 Hz with 3rd and 5th harmonics at 0.7 A and 0.3 A respectively. The current fundamental phase angle is 12 ° relative to the voltage fundamental. The current 3rd harmonic has a phase angle of +25 ° relative to the current fundamental, for example, the phase angle between the 3rd current harmonic and the 3rd voltage harmonic is 25 ° + (3 x 12 °) = 61 °. As the current 5th harmonic is not matched by a voltage 5th harmonic, there is no 5th harmonic power contribution.

Voltage uncertainty values are given in "Voltage and Sine Amplitude Specifications" and "Voltage DC and Harmonic Specifications", current uncertainty values are given in "Current Sine Amplitude Specifications" and "Current DC and Harmonic Amplitude Specifications". Phase uncertainty values are given in "Current to Voltage Phase Specifications". The accuracy used is that of the 6100B.

Converting all values to ppm, accuracy contribution at the fundamental frequency

$$u(V_1) = 112\,ppm + \frac{0.0044\ \ V \times 10^6}{109\ \ V} = 152\,ppm$$

$$u(I_1) = 164\,ppm + \frac{0.00024\ \ A \times 10^6}{7\ \ A} = 198\,ppm$$

$$u(phase_1) = \left(1 - \frac{\cos(12 + 0.003)}{\cos(12)}\right) \times 1e6 = 11\,ppm$$

Combined accuracy for the fundamental frequency components:

$$u(P_1) = \sqrt{152^2 + 198^2 + 11^2} = 250\,ppm$$

Power in the fundamental frequency:

$$P_1 = V_1 I_1 \cos\Phi_1 = 109 \times 7 \times 0.9781476 = 746.3266\ \ Watts \text{ so:}$$

$$u(P_1) = 250 \times 10^{-6} \times 746.3266 = 0.1866\ \ Watts$$

Accuracy contribution for the 3rd harmonic

$$u(V_3) = 122\,ppm + \frac{0.0044\ \ V \times 10^6}{15\ \ V} = 415\,ppm$$

$$u(I_3) = 191\,ppm + \frac{0.00024\ \ A \times 10^6}{0.7\ \ A} = 534\,ppm$$

$$u(phase_3) = \left(1 - \frac{\cos(61 + 0.009)}{\cos(61)}\right) \times 1e6 = 283\,ppm$$

Combined accuracy for the 3rd harmonic components

$$u(P_3) = \sqrt{415^2 + 534^2 + 283^2} = 733\,ppm$$

Power in the 3rd harmonic components:

$$P_3 = V_3 I_3 \cos\Phi_3 = 15 \times 0.7 \times 0.484810 = 5.0905\ \ Watts \text{ so:}$$

$$u(P_3) = 733 \times 10^{-6} \times 5.0905 = 0.003732\ \ Watts$$

Total power $P = P_1 + P_3 = 746.3266 + 5.0905 = 751.4171$ Watts

From:

$$u_c(P) = \sum_{i=1}^{N} c_i . u(P_i)$$

$$u_c(P) = \frac{746.3266}{751.4171} \times 0.1866 + \frac{5.0905}{751.4171} \times 0.003731 = 0.1854 \; Watts$$

$$Power \;\; Accuracy = 751.4171 \pm 0.1854 \;\; Watts$$

Reactive Power Calculation Methods

Under pure sinusoidal conditions, Apparent Power (S), Power (P) and Reactive power (Q) are related by:

$S^2 = P^2 + Q^2$. This relationship is known as the Power Triangle. When either the voltage or current waveform is not sinusoidal, the power triangle is not satisfied by this equation. This has lead to various attempts to better define Reactive Power (Q) but no single definition has been agreed. The difficulty is that Q is used for a number of different calculations including transmission line efficiency and voltage line drop. The 6100B allows users to select the definition that best meets their needs. The following methods are supported:

Budeanu	Fryze
Kusters and Moore	Shepherd and Zakikhani
Sharon / Czarnecki	IEEE working group

Because of the complexity of the subject, definition of the methods listed is beyond the scope of this document. References to relevant documentation are provided at the reference

Reactive Power

For reactive Power (Q) calculate $u\,\phi(Q)$ from

$$u(Q) = (1 - \frac{\sin(\Phi \;\; + u(\phi))}{\sin(\Phi)})$$

The method used for calculation of reactive power in non-sinusoidal conditions is user selectable.

References

6100B reactive power calculations are guided by the published work of Dr. Stefan Svensson:

Svensson, S., (1999), Power Measurement Techniques for Nonsinusoidal Conditions, Chalmers

Other pertinent papers are:

Budeanu, C., (1927), "Reactive and fictitious powers", *Rumanian National Institute*, No.2.

Czarnecki, L. S., (1885), "Considerations on the reactive power in nonsinusoidal situations", *IEEE Trans. on Inst. and Meas.*, Vol. 34, No. 3, pp399-404, Sept.

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Filipski, P., (1980), "A new approach to reactive current and reactive power measurements in nonsinusoidal systems", *IEEE Trans. on Inst. and Meas.*, Vol. 29, No. 4, pp423-426, Dec.

Fryze, S., (1932), "Wirk- Blind- und Scheinleistung in elektrischen Stromkreisen mit nichtsinusformigen Verlauf von Strom und Spannung", *Elektrotechnische Zeitschrift*, No25, pp 596-99, 625-627, 700-702.

Kusters, N. L. and Moore, W. J. M., (1980), "On the definition of reactive power under nonsinusoidal conditions", *IEEE Transaction on Power Apparatus and Systems*, Vol PAS-99, No. 5, pp1845-1854, Sept/Oct.

Sharon, D., (1973), "Reactive power definition and power factor improvement in non-linear systems", *PROC. IEE,* Vol. 120, No. 6, pp 704-706, July.

Shepherd, W. and Zakikhani, P., (1972), "Suggested definition of reactive power for nonsinusoidal systems", *PROC. IEE,* Vol. 119, No. 9, pp 1361-1362, Sept.

IEC, Reactive power in nonsinusoidal situations, Report TC 25/wg7.

Ordering information

Model

6100A Electrical Power Standard Master comprises:
- One phase, (one voltage channelto 1000 V, one current channel to 21 A)
- User controls and display system
- Interfacing via GPIB/RS232
- Interfacing to Auxiliary Unit
- Line cord
- Lead kit
- User manual

6101A Auxiliary Power Standard comprises:
- One phase, (one voltage channel to 1000 V, one current channel to 21 A)
- Cable and interfacing to connect to Master
- Line cord
- Lead kit

6100A/80A Electrical Power Standard Master comprises:
- One phase, (one voltage channel to 1000 V, one current channel to 80 A)
- User controls and display system
- Interfacing via GPIB/RS232
- Interfacing to Auxiliary Unit
- Line cord
- Lead kit
- User manual

6101A/80A Auxiliary Power Standard comprises:
- One phase, (one voltage channel to 1000 V, one current channel to 80 A)
- Cable and interfacing to connect to Master
- Line cord
- Lead kit

6100A/E Electrical Power Standard Master comprises:
- One phase, (one voltage channel to 1000 V, one current channel to 21 A) with energy counting option fitted
- User controls and display system
- Interfacing via GPIB/RS232
- Interfacing to Auxiliary Unit
- Line cord
- Lead kit
- User manual

6100A/E/80A Electrical Power Standard comprises:
- One phase, (one voltage channel to 1000 V, one current channel to 80 A) with energy counting option fitted
- Cable and interfacing to connect to Master
- Line cord
- Lead kit
- User manual

Complete systems

6120A complete 2-phase system comprises:
- One 6100A
- One 6101A

6130A complete 3-phase system comprises:
- One 6100A
- Two 6101As

6140A complete 4-phase system comprises:
- One 6100A
- Three 6101As

Complete 6100A/80A systems

6120A/80A complete 2-phase system comprises:
- One 6100A/80A
- One 6101A/80A

6130A/80A complete 3-phase system comprises:
- One 6100A/80A
- Two 6101A/80As

6140A/80A complete 4-phase system comprises:
- One 6100A/80A
- Three 6101A/80As

Complete 6100A/E systems

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- One 6101A

6130A/E complete 3-phase system comprises:
- One 6100A/E
- Two 6101As

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- One 6100A/E
- Three 6101As

Complete 6100A/E/80A systems

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- Two 6101A/80As

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- One 6100A/E/80A
- Three 6101A/80As

Accessories

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6100A/6101A Transit case
Y6100
6100A/6101A Rack Mount Kit

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